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# GENERAL PHYSIOLOGY AND ITS RELATION TO MORPHOLOGY.[1]

### By C. O. Whitman.

It is only as a zoologist that I venture to discuss this subject; and only in this capacity that I undertake to defend the proposition, that *general zoological physiology* is the promising field in which morphology and physiology may work most profitably together.

Morphology and physiology are two quite distinct sides of biology, each with definite and constant peculiarities of method and aim; but these two sides are only the statical and the dynamical aspect of one and the same thing; one presents the *feature*, the other the *expression*. It is only as a matter of convenience that these two aspects are dealt with separately; they are complemental, and have their full meaning only when united. The same function may appear in different forms, but a knowledge of the forms is nevertheless indispensable to an understanding of the function, and, conversely, the function must be known before we can arrive at a complete interpretation of the form. The best interests of biology demand that morphology and physiology should be kept in working contact. That is the lesson of the hour, which thoughtful investigators on both sides are coming more and more to realize. The separation of these two great branches of biology has been carried to an extreme that impedes the progress of both—an extreme that is unnatural and that has resulted from keeping physiology too exclusively in the service of medicine.

Physiology has come to mean, in practice at least, little more than the science which treats of the functions of fully developed organs. That this is an important side of physiology goes without saying, but there is another side no less important, which has been hitherto left almost wholly to morphologists. That we have to deal with functions of organisms as well as with functions of organs, is a truth that could not escape the student of Darwin's or Wallace's works. Still we have just begun to heed the fact that the broader physiology of the future must include the biological economy of organisms as well as the functional economy of organs. I repeat *the biological economy of organisms* must become an integral part of physiology, not only in theory, but in practice as well.

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[1] From the Fifth Annual Report on the Marine Biological Laboratory of Wood's Holl, 1892.

The activities and inter-relations of *organisms* bear the same relation to their morphology, as do the functions and correlations of *organs* to their anatomy. The former activities differ from the latter only in degree, just as an organism differs from an organ only as a composite differs from a simple. As the morphology of organisms includes organology, so the physiology of organisms embraces the functions of organs. As the one covers all organic forms from the most minute and simple up to the most highly differentiated and complex, so the other covers all vital phenomena, whether manifested in the smallest particle of living protoplasm, in a cell, a special tissue, an organ, an organism, a species, or any group of organisms. Form and function are always the two aspects, inseparably linked together throughout the entire organic world.

The work of the physiologist runs perfectly parallel with that of the morphologist, and wherever the one divides there the other divides, and for precisely similar reasons. We have the morphology of adult individuals, likewise the physiology; we have the morphology of the developing individual (ontogeny), likewise embryological physiology (" physiontogeny "); then we have the morphology of the species (phylogeny), and along side the physiology, or the phylogeny of functions (" physiophyly, " Haeckel).

*Metaphysiosis*[2] is as old and as universal as metamorphosis, and to attempt to explain functions as we find them to-day without considering their historical development, is in many cases at least, as idle as trying to account for the specified forms

[2] This word suggests itself so readily, that it will hardly be recognized as novel; it is at least self-defining.

of existing organisms without the aid of their genealogy. Monumental failures of this kind might be cited on both sides; but it may be said that morphologists have almost universally abandoned this standpoint, while physiologists have quite generally adhered to it. It is the one-sided anthropocentric development of physiology that has retarded its progress, and that still waits to be corrected. Presumptuous as such statements may appear, coming from a morphologist, they are nevertheless true and must be declared so long as the malady of one of the twin branches of biology remains as the affliction of the other. So long as such fundamental functions of organisms as heredity, variation, adaptation, are neglected by physiologists, so long will physiology have to bear the reproach of having some of its more inviting fields pre-occupied and developed by morphologists.

What processes of life are more universal or more fundamental than those exhibited in and about the dividing nucleus? What function of living protoplasm has more to tell us about how the organism comes into existence and how the foundation is laid for the development of all the higher functions, than that of cleavage? What phenómenon of life stands more in need of a physiological explanation than that of sex differentiation? What question has a more direct practical bearing on the education and development of the human race than that of the transmission of acquired characters? What functions of more transcendent interest than those of the various sense organs? Where could a more beautiful example of the evolution of function be found than is furnished in our special senses? How intensely interesting the subject of the derivation of such functions! Will the physiologist, or his protègè the psychologist, give a share of attention to these important matters, or must the morphologist not only find the problem but work it out whenever it falls within the range of evolution? That would mean working under all the disadvantages attending the separation of two co-ordinate branches which are complemental one to the other. Morphology would lose its natural helpmate, and physiology would forsake its best guide. Morphology analyses the organic machine and thus lays the foundation for understanding its physiological use; physiology puts the suggestions of morphology to the test of experiment, and elucidates the dynamical side of the machine. What the machine consists of and what it can do, go together to make up a full concept of its structure and its functions. But the concurrence of the two sciences does not stop here. Morphology raises the question, how came the organic mechanism into existence? Has it had a history, reaching its present state of perfection through a long series of gradations, the first term of which was a relatively simple stage? The embryological history is traced out and the paleontological records are searched until the evidence from both sources establishes the fact, that the organ or organism under study is but the summation of modifications and elaborations of a relatively simple primordial. This point settled, physiology is called upon to complete the story. Have the functions remained the same throughout the series, or have they undergone a series of modifications, differentiations, and improvements more or less parallel with the morphological series? To answer this question, physiology has to appeal to the same sources of evidence as does morphology, namely, paleontology and embryology.

The paleontolgical series of forms cannot of course be experimented with; but form and function are so correlated that the latter may often be inferred from the former, and *vice versa.* The embryological series, often including free larval stages, furnishes one of the grandest fields for experimental study. Here the physiologist has an opportunity not only to study by experiment but also by direct observation and inference, and thus to join hands with the morphologist both in methods and results.

We are compelled to recognize different *orders* of individualities,—as the cell, the tissue, the organ, the organism, the corm—and of course every order must have its physiology as well as its morphology. Morphology and physiology are co-extensive, each claiming the whole organic world—as it was, as it is, and as it becomes. So long as we contradistinguish form and function, we must abide by the logic of definition. We cannot reduce the circumference of the animate world, however many radii and concentric circles we draw around our specialties. We may limit the province but not the realm. If we limit our study to man, we do not annihilate his relations to the rest of the animate world. Human physiology and human morphology represent only the latest terms of series stretching back to remote initial terms. The complexities of structure and function of the later terms we can never hope to understand until, through the study of a sufficient number of mean terms, we are able to determine the initial ones.

Three general series, each more or less incomplete, are accessible to study: (1) The systematic series, consisting of adult organisms, (2) the paleontological series, and (3) the developmental series. Morphology approaches these series by *comparative* study, and seeks to make each contribute as complete a story as possible. The same sources and the same method are open to physiology. The importance of the comparative method in physiology and the intimate co-relationship of physiology with morphology are well exemplified in a charming little treatise by Metschnikoff on "*La Pathologie Comparée de l'Inflammation*"—a work that must be reckoned as one of the fairest gems that adorn the annals of the Pasteur Institute. This monumental work shows how medicine itself must take its lessons from *comparative biology,* and approach its work from the standpoint of evolution.

The history of morphology and physiology is one continuous illustration of their inter-dependence. When the famous Harvey was asked what led him to think of the circulation of the blood he at once referred the original suggestion to one of the morphological features of the vascular apparatus—the valves and their arrangement. The hint furnished by structure was then followed up and tested by experiment, and the result was a discovery that brought the position of valves, pulsation of the heart, effects of ligatures, and other facts into rational relation to one another.

The history of theories of generation furnishes a capital example of how physiological speculation has been guided, checked, and corrected by morphological discovery. The old doctrine of preformation, or pre-existence of organisms in the germ, and the notion of the inclusion of one germ preformation within another, was certainly strongly suggested by the unfolding of plant buds and by the metamorphoses of insects; but as soon as it became possible to examine more minutely the phases of development, it was found that the fine-spun theories of Bonnet and Haller were refuted by morphological facts, and the doctrine of epigenesis, defended by Aristotle and Harvey, was led to triumph through the observations of Caspar Friedrich Wolff.

Our special senses have afforded one of the most fertile fields for speculative physiology. It is needless to dwell on antiquated hypotheses of "vital spirits" residing in the nerves, of a subtle nervous humor, or "imponderable fluid" drawn from the blood and secreted by medullary matter (Cuvier). The history of the hypotheses of life, sensation and volition are largely, as Whewell has well remarked, "the story of the *failures* of physiological speculation." It is to the cultivation of the morphological sciences that physiology owes in a very large measure, its deliverance from the temptation to stray into the region of metaphysics.

As morphology furnishes the ground structure on which physiology operates, it naturally takes the place of pioneer and guide; but if permitted to wander too far in advance, it soon finds itself entangled with physiological problems with which it is not prepared to cope, and its efforts to release itself often end in sterile speculation. The workers on both sides should therefore advance abreast, in hand to hand contact. It is only in such reciprocally helpful relations that specialists can attain the highest possible individual development, and it is only when morphological and physiological experience and knowledge combine, that biology can accomplish such brilliant feats as that of Cuvier in reconstructing an extinct organism from its fragmentary remains.

The association of morphological and physiological research enlarges the field of vision on both sides, reduces the chances of useless labor, corrects false notions, stimulates inquiry, converts half views into whole views, and withal secures mutual respect.